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OF
ARTILLERY INSTRUMENTS AND RANGE-FINDERS

PART I
1933

SECTION 14

CALCULATOR, BALLISTIC CORRECTION, NO. 1, MARK I

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H. J. Creedy
A. G.

THE WAR OFFICE,
30*th September*, 1937.

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CHAPTER I

PRINCIPLE

(Plate 1)

The *ballistic correction calculator* is designed to evaluate the corrections to range and bearing which are necessitated when any of the following meteorological conditions differ from normal :—

(i) Wind.
(ii) Air temperature.
(iii) Barometer.

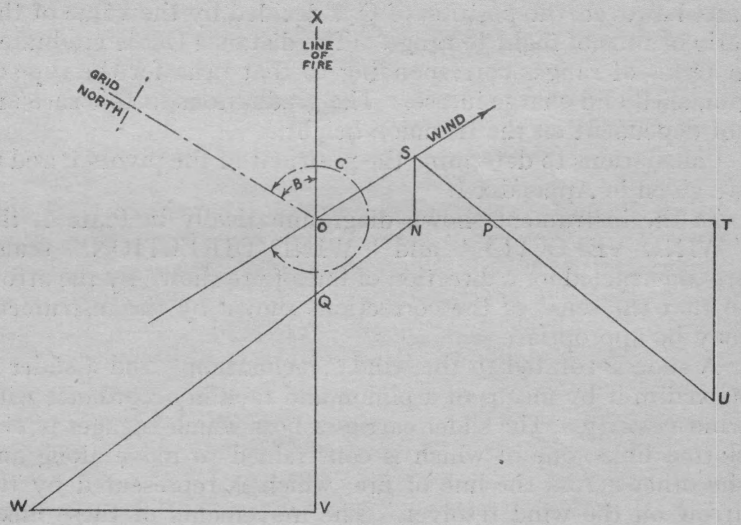


FIG. 1

In Fig. 1 the line of fire is represented by VOX and the direction of the wind by OS, which is also the measure of its velocity. B is the bearing of the line of fire and C is the bearing of the wind. The angle XOS gives the wind " inclination " ; it is the difference between B and (C $\pm$ 180 degrees).

OS is a measure of the effect of the wind in unit time. It is resolved into two components, " along " (NS) and " across " (ON) the line of fire.

The triangles SNP and UTP are similar, because the angles SNP and UTP are right angles and the angles SPN and UPT are equal and opposite.

The length NS is proportional to the velocity of the wind in the " along " direction. The position of the line TU is fixed, so that its length is dependent on both the length NS and the position of P. If the length NP is made proportional to the time of flight, TU will then be proportional to the product of the time of flight and the wind velocity " along ", i.e. to the range correction needed for wind.

The length NP is graduated in terms of range corresponding to the times of flight for the type of gun, shell and charge in use. The graduations are also dependent on the trunnion height.

In the case of the " across " or bearing correction, the range to the target must be considered as well as the time of flight, since

$$\text{Bearing correction} = \frac{\text{Speed across} \times \text{Time of flight.}}{\text{Range}}$$

The similarity of the triangles NOQ and WVQ shows that the bearing correction for wind is proportional to VW. In this case, however, the position of Q is decided by the value of the ratio of time of flight to range. The distance OQ is graduated in terms of ranges corresponding to that ratio for the type of gun, shell and charge in use. The graduations in this case are not dependent on the trunnion height.

Calculations to determine the positions of the pivots P and Q are given in Appendix I.

In the instrument shown diagrammatically in Plate 1, the " WIND VELOCITY " and " WIND DIRECTION " scales are constructed for a direction of line of fire shown by the arrow so that the sense of the corrections shown by the instrument may be appropriate.

A slide is rotated to the wind " inclination " and a slider is moved in it by means of a pinion and rack in accordance with wind velocity. The slider carries a boss which engages in two slotted links, one of which is constrained to move along and the other across the line of fire, which is represented by the arrow on the wind resolver. The movements of these links, therefore, represent the resolved components of the effect of the wind in unit time.

To the end of each link is pivoted an arm which passes through a movable swivel constrained to move along a slide. The movable swivel carries an index against which a scale of ranges, fixed parallel with the slide, can be read. The other end of each arm passes through another movable swivel constrained to move in guides at right angles to the first and carrying an index against which a correction scale may be read.

Air temperature and barometer do not affect line, so that the bearing correction for " meteor " can be read off the appropriate scale without further adjustment.

Air temperature and barometer do, however, alter range, and the " meteor " correction must counter their effect. The reading of the range correction scale can be made to include the correction for them, known as the " co-efficient correction ", with sufficient accuracy by moving it along its slides. The necessary movement is brought about by means of a third arm, similar to the two arms already described, passing through a movable swivel with an index, and a third range scale. When air temperature and barometer are normal, the range correction scale shows the wind correction as evolved by the wind resolver. When the barometer varies from normal, a scale plate with a scale graduated in inches of mercury representing barometric pressure along one edge and with an index at the other edge is moved so that the barometer reading is shown by an index on a fixed part of the instrument. An air temperature scale plate, carried on a bar, is then moved so that the air temperature is shown by the index on the barometer scale plate.

The bar that carries the air temperature scale plate also carries a pivot for one end of the third arm. The other end of the arm passes through a swivel which moves the range correction scale plate and varies the correction shown by the index.

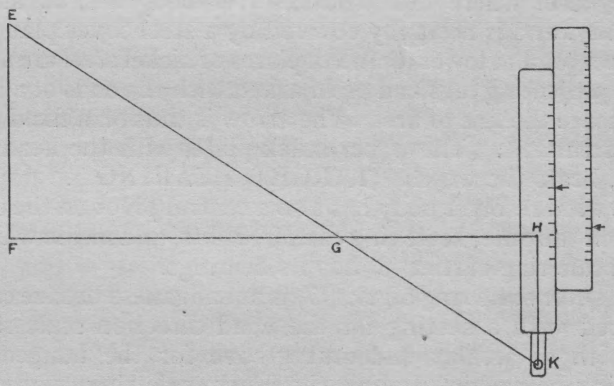


FIG. 2

The distance HK (Fig. 2) is proportional to the combined correction for unit time of flight. The distance FE represents the movement of the range correction scale. The ratio of FE to HK is decided by the position of G and a scale of ranges is provided to indicate its correct position. The position of G is dependent on the trunnion height. A series of range scale plates is provided, each of which is suitable for a certain range of heights.

Batteries are issued with the appropriate range scale plates.

CHAPTER II

DESCRIPTION

(Plate 2)

The calculator is mounted on an aluminium alloy base (1) webbed on the under side for strengthening purposes. The upper surface is prepared to receive the components of the instrument and has the contractor's name, year of supply and registered number engraved on it. It has four holes near its corners to accommodate half-inch securing bolts, by which the calculator may be mounted on a wall, and is recessed at the top and bottom to receive the cover. A slot is provided for the cover lock. The base is finished in service colour enamel except on the bearing surfaces.

The wind resolver body (2) is a square-sectioned gunmetal casting with two projecting lugs on opposite sides and is secured to the base by four screws. The lower lug is furnished with a knurled-headed clamping screw (3). A circular hole is left in the base, where the wind resolver body fits, to assist in assembly, and is normally covered by a steel cover plate (4).

Upper (5) and lower (6) index plates of nickel steel are screwed to the projecting lugs and are marked with the ends of an arrow to indicate the line of fire. The arrow is thus on a fixed part of the instrument. The upper index plate, with the head of the arrow, bears the words " TARGET BEARING ".

The wind resolver body has also a central pivot on the outside of which the outer scale ring carrier (7) fits, and inside which the inner scale ring carrier (8) has its bearings.

The outer scale ring carrier (7) is a manganese bronze casting, prepared with a seating for the wind direction scale ring (9) and with a circular undercut groove for the flange of the clamping bolt which clamps the inner scale ring carrier to it. The wind direction scale ring is secured to it by three screws. It can be clamped to the wind resolver body by the knurled-headed clamping screw on the lower projection.

The wind direction scale ring (9) is of nickel silver, graduated in bearings, engraved every five degrees and figured every ten degrees.

The inner scale ring carrier (8) is of manganese bronze and has a circular undercut groove machined in it to accommodate the flange of the clamping bolt which secures the wind velocity scale index disc (10) to it, and is provided with a seating for the

wind velocity scale ring (11). It is bored centrally with an irregular hexagonal hole, and is engraved with the words " WIND DIRECTION " and with an index arrow. Two thumb pieces are riveted to it.

The wind velocity scale ring (11), which is secured to the inner scale ring carrier by three screws, is of nickel silver. It has a scale of wind velocities, from 0 to 90 feet per second, engraved on it, marked every two feet and figured every ten feet.

The wind velocity scale index disc (10) is of manganese bronze, cast with wing projections to enable it to be turned, and has a hole near its periphery through which the stem of the screw clamp passes. An irregular hexagonal hole is bored centrally through it and it is engraved with the words " WIND VELOCITY " and with an index arrow.

The irregular hexagonal hole of the inner scale ring carrier fits over a similar hexagon on a journal bearing formed on the slide. This journal bearing rotates inside the pivot of the wind resolver body and provides the bearing for the inner scale ring carrier.

The irregular hexagonal hole of the wind velocity scale index disc fits over a similar hexagon on the pinion spindle (12).

The pinion spindle (12) can be rotated inside the journal bearing on the slide. It is screw-threaded to take a nut which retains the wind velocity scale index disc in position. A pinion formed on the other end of the spindle engages with a rack attached to the slider (13).

The pinion spindle is bored centrally with a channel which serves to lubricate all the bearings. This channel is closed by an oil-hole screw (14).

The slider (13) is of steel and consists of a body, shaped externally to fit the slide, with a boss formed on it. Inside, it is channel-shaped and has the rack secured along one side by three screws.

On the boss are mounted two rollers, separated by a plain washer and secured by a D-washer and nut.

These rollers engage in slots in two links (15) which actuate the range scale plate reader arms. The links slide in the wind resolver body and in grooves machined in the base.

The upper link moves in the " across " direction and the lower link in the " along " direction.

The upper link carries at its outer end a pivot plate (16), secured below it by a screw which passes through an elongated hole in the link. The lower link carries, at its outer end, a pivot plate (18), secured above it by a screw. The pivots for the range scale plate reader arms (17) are riveted to the pivot plates.

Each range scale plate reader arm (17) is of steel, secured in

position by a washer and nut, and passes through a No. 1 swivel and a No. 2 swivel.

The No. 1 swivel (19) pivots on a manganese bronze range scale plate reader (20) which moves along a range scale plate reader slide (21) screwed to the base. A knurled-headed clamping screw (22) bearing against a flat spring serves to clamp the reader to the slide when required. An index arrow is engraved on the upper surface of the reader to read against a range scale plate screwed to the base. The No. 2 swivel (23) houses the end of the reader arm and is screwed into a steel plate bar (24) which slides in a groove prepared in the base.

The bearing correction scale plate (25) is divided every ten minutes and figured every degree up to five degrees " RIGHT " and " LEFT ".

The range correction scale plate (26) is divided every 50 yards and figured every 500 yards up to 3000 yards " ADD " and 4000 yards " DROP ".

Three range scale plates are provided for each instrument. They are the " range wind " (27), " co-efficient correction " (28) and " bearing wind " (29) scale plates. These names indicate their position and use. Since the range wind correction and the co-efficient correction vary with the trunnion height of the battery, series of range wind and co-efficient correction scale plates, corresponding to varying trunnion heights, are provided for each combination of gun, shell and charge ; but one bearing wind scale plate is sufficient for each combination.

Range scale plates are engraved with scales of ranges appropriate to the gun, shell and charge. Each plate carries two scales, except in the cases where only one charge is provided.

In addition to the scales each face has the charge engraved at one end. One face of each plate has engraving to show the trunnion height for which it is suitable (except bearing wind plate) and the nomenclature of the plate (*see* Plate 2). The other face has engraving to show the types of shell for which the plate is suitable and carries the words " RANGE WIND ", " CO-EFFICIENT CORRECTION " or " BEARING WIND " to indicate the use of the plate.

The range scale plates are arranged in a numbered series according to the lists on pages 11 to 13.

Action

The target bearing is set against the index on the upper index plate by rotating the outer scale ring carrier, and the wind direction is set by rotating the inner scale ring carrier until the index arrow on it shows the correct reading on the outer scale ring. The effect of these two settings is that the inner scale ring, and with it the slide, has been turned, relatively to

the base, through an angle which is the difference between target bearing and wind direction, i.e. wind " inclination ".

The wind velocity scale, the wind velocity scale index disc, and therefore the pinion, have all rotated with the inner scale ring carrier and the slide, so that there has been no motion of the rack and the slider.

The slide is now set at wind " inclination " without any rotation of the pinion or movement of the slider.

If the inner scale ring carrier is now clamped and the wind velocity is set by rotating the wind velocity scale index disc, the pinion rotates and the slider travels in the slide until the boss on it has moved through a distance proportional to the wind velocity.

One of the links engaging with the boss has now been moved a distance proportional to the " along " component of the wind velocity, and the other a distance proportional to the " across " component.

PLATES, RANGE SCALE, NO. 1 BALLISTIC CORRECTION CALCULATOR

B.L. 6-INCH MARK VII GUN

Trunnion height	*Projectile*	*Charge*	*Name of plate*	*Plate No.*
feet				
15 to 80	6 c.r.h. H.E. or shrapnel	Full & $\frac{1}{2}$	Range wind	5
,,	,, ,,	,,	Co-efficient correction	8
,,	6 c.r.h. H.E. or C.P.B.C.	,,	Range wind	11
,,	,, ,,	,,	Co-efficient correction	14
80 to 175	,, ,,	,,	Range wind	12
,,	,, ,,	,,	Co-efficient correction	15
,,	6 c.r.h. H.E. or shrapnel	,,	Range wind	6
,,	,, ,,	,,	Co-efficient correction	9
270 to 385	,, ,,	,,	Range wind	7
,,	,, ,,	,,	Co-efficient correction	10
,,	6 c.r.h. H.E. or C.P.B.C.	,,	Range wind	13
,,	,, ,,	,,	Co-efficient correction	16
	,, ,,	,,	Bearing wind	2
	6 c.r.h. H.E. or shrapnel	,,	Bearing wind	1

PLATES, RANGE SCALE, NO. 1 BALLISTIC CORRECTION CALCULATOR

B.L. 9·2-INCH MARK X GUN

Trunnion height	*Projectile*	*Charge*	*Name of plate*	*Plate No.*
feet				
80 to 175	2 c.r.h. H.E. and A.P.C.	Full & ¾	Range wind	25
,,	,, ,,	,,	Co-efficient correction	29
,,	4 c.r.h. H.E. and A.P.C.	,,	Range wind	17
,,	,, ,,	,,	Co-efficient correction	21
,,	6 c.r.h. A.P.C.	Full	Range wind	35
,,	,,	,,	Co-efficient correction	36
175 to 270	2 c.r.h. H.E. and A.P.C.	Full & ¾	Range wind	26
,,	,, ,,	,,	Co-efficient correction	30
,,	4 c.r.h. H.E. and A.P.C.	,,	Range wind	18
,,	,, ,,	,,	Co-efficient correction	22
,,	6 c.r.h. A.P.C.	Full	Range wind	46
,,	,,	,,	Co-efficient correction	47
270 to 385	2 c.r.h. H.E. and A.P.C.	Full & ¾	Range wind	54
,,	,, ,,	,,	Co-efficient correction	55
,,	4 c.r.h. H.E. and A.P.C.	,,	Range wind	52
,,	,, ,,	,,	Co-efficient correction	53
,,	6 c.r.h. A.P.C.	Full	Range wind	56
,,	,,	,,	Co-efficient correction	57
385 to 485	2 c.r.h. H.E. and A.P.C.	Full & ¾	Range wind	27
,,	,, ,,	,,	Co-efficient correction	31
,,	4 c.r.h. H.E. and A.P.C.	,,	Range wind	19
,,	,, ,,	,,	Co-efficient correction	23
485 to 615	4 c.r.h. H.E. and A.P.C.	,,	Range wind	44
,,	,, ,,	,,	Co-efficient correction	45
,,	6 c.r.h. A.P.C.	Full	Range wind	48
,,	,,	,,	Co-efficient correction	49
745 to 925	2 c.r.h. H.E. and A.P.C.	Full & ¾	Range wind	28
,,	,, ,,	,,	Co-efficient correction	32
,,	4 c.r.h. H.E. and A.P.C.	,,	Range wind	20
,,	,, ,,	,,	Co-efficient correction	24
,,	6 c.r.h. A.P.C.	Full	Range wind	50
,,	,,	,,	Co-efficient correction	51

PLATES, RANGE SCALE, NO. 1 BALLISTIC CORRECTION CALCULATOR—*contd.*

B.L. 9·2-INCH MARK X GUN—*contd.*

Trunnion height	*Projectile*	*Charge*	*Name of plate*	*Plate No.*
feet				
1100 to 1400	4 c.r.h. H.E. and A.P.C.	Full & ¾	Range wind	33
,,	,, ,,	,,	Co-efficient correction	34
	2 c.r.h. H.E. and A.P.C.	,,	Bearing wind	4
	4 c.r.h. H.E. and A.P.C.	,,	Bearing wind	3
	6 c.r.h. A.P.C.	Full	Bearing wind	37
	B.L. 15-INCH MARK I GUN			
15 to 80	4 c.r.h. A.P.C.	Full & ¾	Range wind	42
,,	,,	,,	Co-efficient correction	43
,,	6 c.r.h. A.P.C.	Full	Range wind	40
,,	,,	,,	Co-efficient correction	41
	4 c.r.h. A.P.C.	Full & ¾	Bearing wind	39
	6 c.r.h. A.P.C.	Full	Bearing wind	38
	Q.F. 6-PR. SUB-CALIBRE GUN			
80 to 175	—	—	Range wind	59
,,	—	—	Co-efficient correction	60
270 to 385	—	—	Range wind	61
,,	—	—	Co-efficient correction	62
			Bearing wind	58

CHAPTER III

METHOD OF USE

To avoid congestion in floor space in the battery plotting room, it is convenient to fix the calculator in a vertical position on the wall near the travel setters of the fire direction table detachment which works it.

As the calculator is not corrected for any particular battery, the barometer readings obtained from the " meteor " telegram must be corrected for half the height of the battery. This is done as a permanent setting by adjusting the calculator according to the following instructions, a copy of which is engraved on a plate secured to the base of the instrument :—

" The calculator is to be adjusted by an officer or qualified artificer when initially setting up, to give 0 correction with normal settings. The barometer scale index to be made to read $30{\cdot}0+{\cdot}001\times H$ inches in this position, where H=height of battery above M.S.L. in feet.

" After the above adjustment, when using the calculator, set the barometer correction scale in accordance with the ' meteor ' reports."

To Set the Calculator

Note.—The range scale plates appropriate to the gun, shell and charge being used should be fixed in their correct positions. As the plates are of identical sizes, care should be taken that the range wind plate is associated with the range correction scale, the bearing wind plate with the bearing correction scale and the co-efficient correction plate with the air temperature and barometer correction. The words " RANGE WIND ", " BEARING WIND " and " CO-EFFICIENT CORRECTION " are engraved on the respective plates.

(*a*) Wind velocity is set by rotating the wind velocity scale index disc until the index mark shows the correct velocity. The index disc should then be clamped by means of the knurled nut.

(*b*) Wind direction is set by rotating the inner scale ring carrier until the index indicates the bearing of the wind, obtained from the " meteor " telegram. It should then be clamped to the outer scale ring carrier by means of the knurled nut. The outer scale ring carrier, carrying the wind direction scale, is then rotated until the target bearing is indicated by

the index arrow on the upper index plate. The outer scale ring carrier may be clamped, if required, by means of its clamping screw.

(*c*) The barometer and air temperature scale plates are set to show the correct readings against their index arrows.

(*d*) The index arrows on the range scale plate readers are set against the range to the target marked on the respective range scale plates.

(*e*) The bearing and range corrections are read as indicated on their respective scale plates.

CHAPTER IV

CARE AND PRESERVATION

NOTE.—Any stripping of the instrument, when necessary, must be carried out only by armament artificers (instruments).

CLEANLINESS

As a considerable amount of the working portion of the instrument is exposed, special consideration must be given to cleanliness. The cover should be removed only when the instrument is required for use. After use the instrument must be wiped over with a slightly oiled rag and the cover replaced.

LUBRICATION

The following portions should be kept lubricated, light mineral oil (M.70) being used :—

(*a*) Pinion spindle. (The oil hole is disclosed on removing a screw from the end of the spindle.)

(*b*) Pivots of range scale plate reader arm.

OVERHAUL

The instrument must be dismantled and thoroughly examined by an armament artificer (instruments) once annually.

APPENDIX I

EVALUATION OF BEARING CORRECTION

Referring to Fig. 3 :—

AD represents the range scale plate reader arm (distance between outer pivots).

O represents the pivot of the range scale plate reader.

" *a* " represents the effect of the " across " component of wind in unit time.

" *d* " represents the bearing correction.

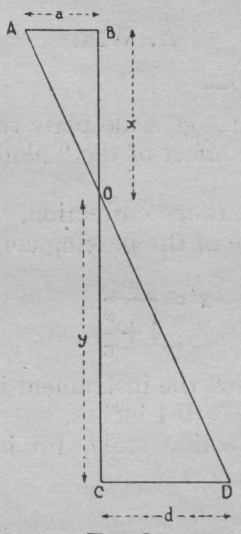


FIG. 3

By the construction of the instrument, $x+y$ is a constant (k)

Then $$\frac{a}{x}=\frac{d}{y} \text{ or } y=\frac{xd}{a}$$

Also $y=k-x$

By subtraction, $x\left(1+\frac{d}{a}\right)=k$

or $$x=\frac{k}{1+\frac{d}{a}}$$

By the scale to which the instrument is designed, for a wind velocity of 10 f.s. " *a* "=0·1 inches.

On the bearing correction scale, 0·6 inches represents 1 degree.

Bearing corrections " d " for ranges and corresponding times of flight are found from the range table, and the position of the range graduation on the range scale plate, which is independent of wind velocity, is found by the equation

$$x=\frac{k}{1+\frac{d}{a}} \text{ where } k=12 \text{ inches and } a=0{\cdot}1 \text{ inches}$$

$$=\frac{12}{1+10d}$$

EVALUATION OF RANGE CORRECTION

A. Wind

Referring to Fig. 4 :—

AD represents the range scale plate reader.

" c " represents the effect of the " along " component of the wind in unit time.

" e " represents the range correction.

Then, as in the case of the bearing correction,

$$x'=\frac{k}{1+\frac{e}{c}}$$

By the scale to which the instrument is designed, for a wind velocity of 10 f.s. " c "=0·1 inches.

On the range correction scale, 1·5 inches represents 1000 yards.

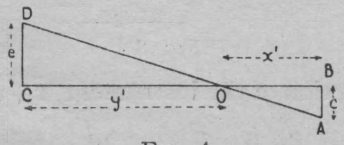


Fig. 4

Range corrections, " e ", for ranges and corresponding times of flight are found from the range table, and the position of the range graduation on the range scale plate, which is independent of wind velocity, is found by the equation

$$x'=\frac{k}{1+\frac{e}{c}} \text{ where } k=12 \text{ inches and } c=0{\cdot}1 \text{ inches}$$

$$=\frac{12}{1+10e}$$

B. Barometer and Air Temperature

The effect of a rise or fall of barometric pressure is calculated for each inch as a percentage of C, the ballistic co-efficient. The instrument caters for a rise of up to 1·4 inches and a fall of 3 inches.

The effect of air temperature changes between 30° F. and 100° F. is also calculated for every 10° difference as a percentage of C.

By the scale of the instrument, 10 per cent. C=1 inch.

Referring to Fig. 5 :—

EH represents the range scale plate reader arm.

"l" represents the movement of the inner end of the range scale plate reader arm due to the combined correction for barometer and air temperature, expressed as a percentage of C.

"m" represents the movement of the range correction scale plate. The position of Q is independent of the value of the percentage of C.

Then, as in previous equations,

$$x''=\frac{k}{1+\frac{m}{l}}$$

$$=\frac{12}{1+m}$$

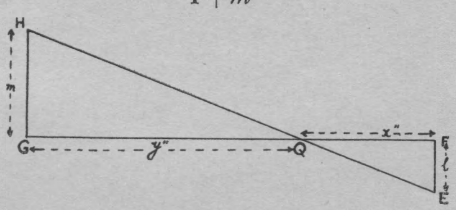


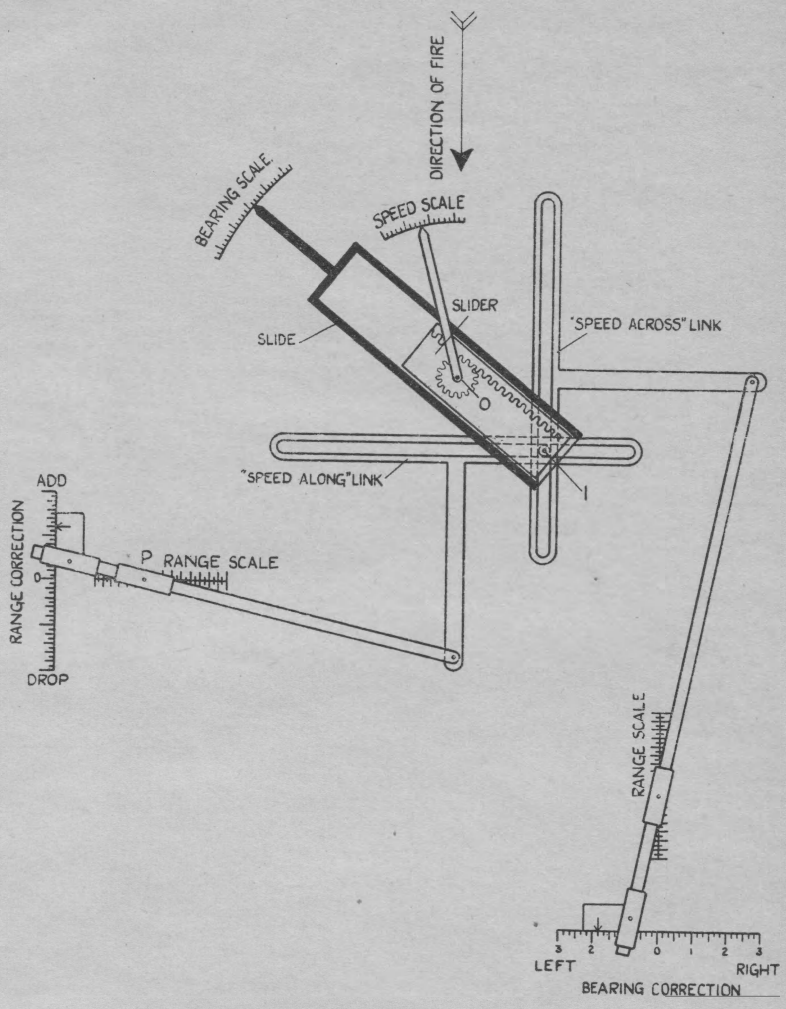
Fig. 5

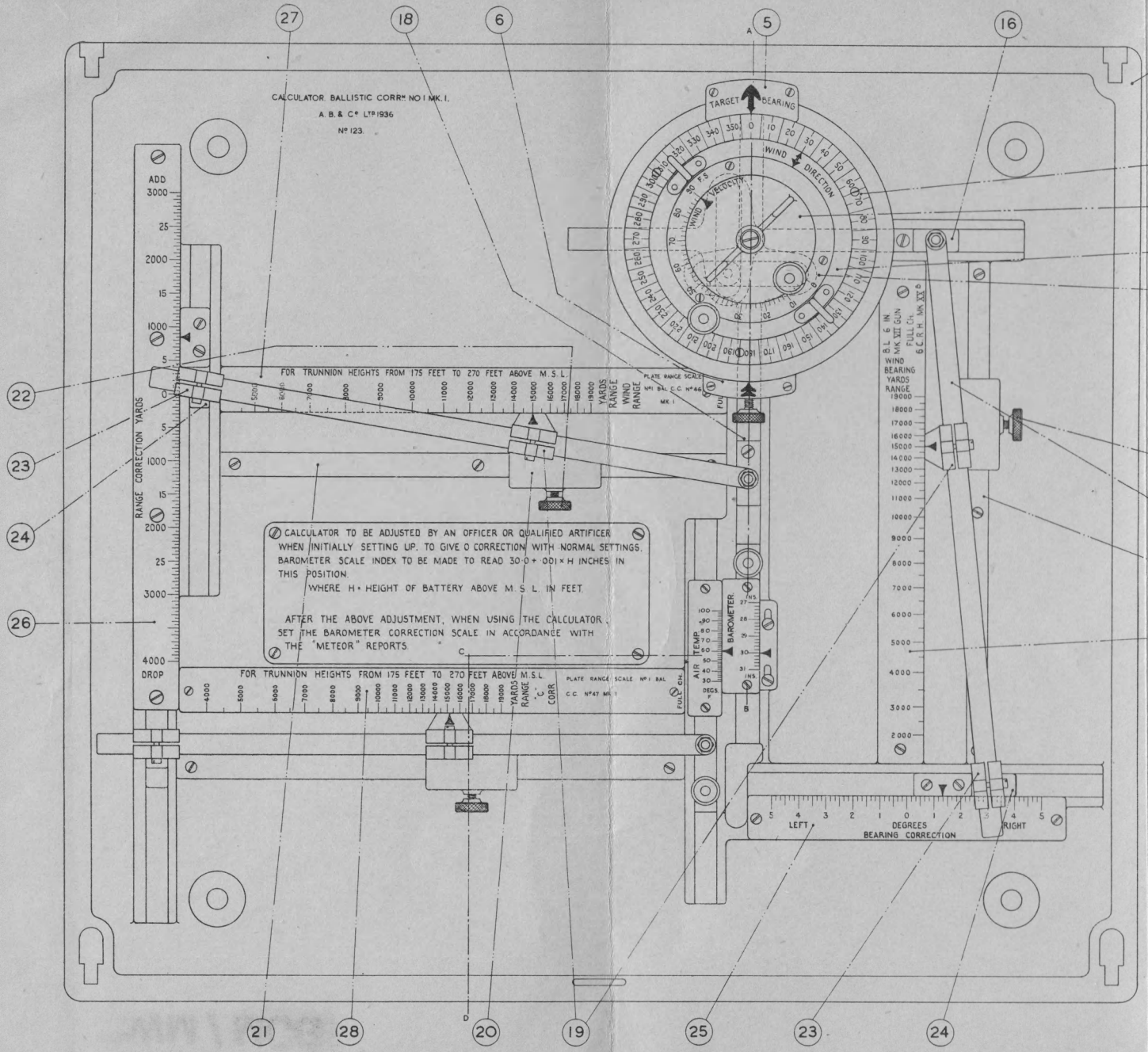
Values of "m" corresponding to range are found from ballistic tables.

(243) Wt. 38677—9733. 2,500. 10/37. W. C. & S., Ltd. **Gp. 394.**

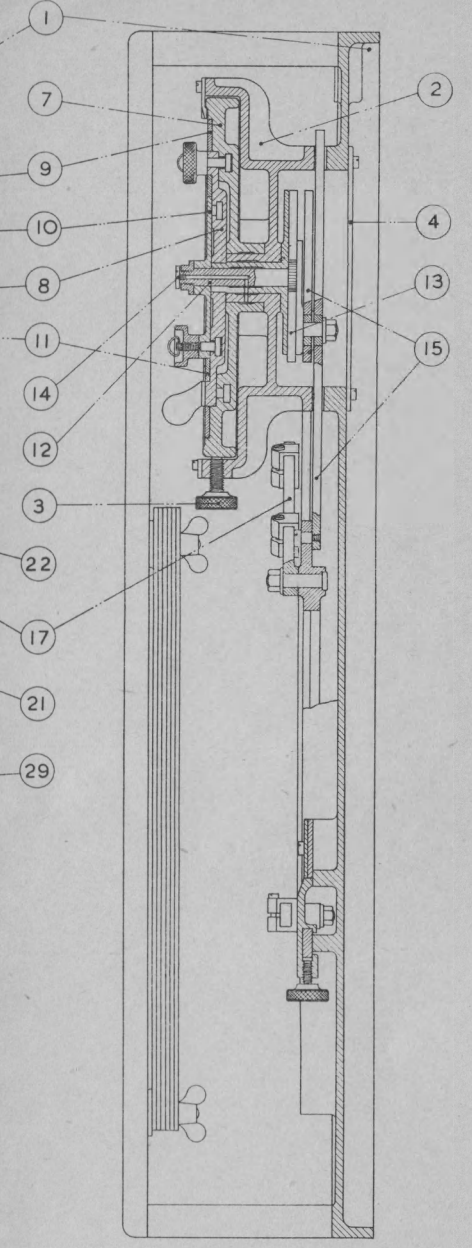
PLATE 1.

CALCULATOR, BALLISTIC CORRECTION, NO. 1, MARK I. KEY DIAGRAM




CALCULATOR BALLISTIC CORRN NO 1 MK. I.
A. B. & Co LTD 1936
No 123.
TARGET BEARING
WIND DIRECTION
WIND VELOCITY
F.S.
ADD
DROP
RANGE CORRECTION YARDS
FOR TRUNNION HEIGHTS FROM 175 FEET TO 270 FEET ABOVE M.S.L.
PLATE RANGE SCALE No 1 BAL C.C. No 46 MK. I
YARDS RANGE
WIND RANGE
FULL CH.
CALCULATOR TO BE ADJUSTED BY AN OFFICER OR QUALIFIED ARTIFICER WHEN INITIALLY SETTING UP, TO GIVE O CORRECTION WITH NORMAL SETTINGS. BAROMETER SCALE INDEX TO BE MADE TO READ 30·0 + ·001 × H INCHES IN THIS POSITION.
WHERE H = HEIGHT OF BATTERY ABOVE M. S. L. IN FEET.
AFTER THE ABOVE ADJUSTMENT, WHEN USING THE CALCULATOR, SET THE BAROMETER CORRECTION SCALE IN ACCORDANCE WITH THE "METEOR" REPORTS.
AIR TEMP
BAROMETER
DEGS. F
INS.
B.L. 6 IN. MK. XIII GUN FULL CH. G.C.R.H. MK. XIX
WIND BEARING YARDS RANGE
LEFT
DEGREES
BEARING CORRECTION
RIGHT
A
B
C
D

PLAN (COVER REMOVED.)



SECTION ON A.B.C.D

(COVER IN POSITION.)